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ABSTRACT

Described are the efforts of the Biomedical Engineering Center in developing devices, particularly the Tufts Interactive Communicator (TIC) for the non-vocal severely physically disabled individual. It is noted that research has been conducted in the following areas: dictionary development, anticipatory communication, symbol communication, symbol printing, and the use of electronic letterboards. (SBH)

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THE TUFTS NON-VOCAL COMMUNICATION PROGRAM

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Summary: This paper describes the efforts of the Biomedical Engineering Center in conducting both research and applied studies in the area of non-vocal communication for the severely physically disabled.

Introduction

The application of technology to the field of Rehabilitation Medicine has offerred the promise of restoring or assisting physical functioning of a severely physically disabled person. A major area of concentration of the Biomedical Engineering Center has been that population which is prevented from normal communication because of a profound motor dysfunction. The lack of speech and writing skills due to muscle incoordination, weakness, or paralysis is evident in disorders such as cerebral palsy, ALS, traumatic head injury, and stroke. While each of these is medically different, the resultant absence of communication is commonly devastating in terms of the person's social, educational, and vocational life.

The Biomedical Engineering Center (BMEC) has staffed its non-vocal communication project with three engineers, an occupational therapist, and a special educator. The goals of the project are to identify technological means of assisting a person to better communicate, and work within the community in the application of assistive devices.

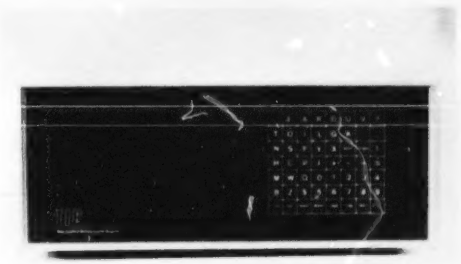
At the present time, the BMEC is under contract to the Massachusetts Bureau of Special Education to work with special needs programs throughout the state providing this type of technical support. As of this writing, twenty-two special education classrooms have been equipped with electronic devices developed by the BMEC. At the same time, the BMEC is working with other agencies and institutions in examining the communication needs of other disabled individuals. Older people who may have been educated before an accident or the onset of a disease do not require educational support, but may require a faster, more powerful device than would a child who is disabled from birth and is learning language in spite of his disability.

A very difficult situation is the older cerebral palsied person who may have been entirely missed by the educational system. He may be extremely intelligent while lacking the formal language skills necessary for effective use of an assistive device.

In order to meet the needs of a varied population, the BMEC has begun to develop a series of communication devices that span the entire range of communication possibilities. This effort will hopefully give the individual a choice of which machine (if any) he wishes to use. The remainder of this paper describes the developments of this program.

The TIC and Related Devices

The Tufts Interactive Communicator[1] (TIC) has been designed as a single switch input typing device that can be operated by a single grossly controllable muscular movement. The need for such an easily operable unit was identified early in the project. While many non-vocal individuals can operate more complex interfaces, the single switch feature finds extensive use with the most severely disabled. The user selects the characters from a visual keyboard that offers rows of characters by successive illumination. A single switch closure chooses the illuminated row, and commands the TIC to scan the characters in that row. A second switch closure chooses a single illuminated character. Once selected, the letter or number is printed on a hardcopy medium, and is displayed electronically. In this way messages are constructed on a letter-by-letter basis.



Front Panel of the TIC
Fig. 1

The TIC that is now in use differs only slightly from that which was developed over 5 years ago. The method of letter selection has proven to be effective and hence is unaltered. The visual keyboard has been rearranged to take advantage of

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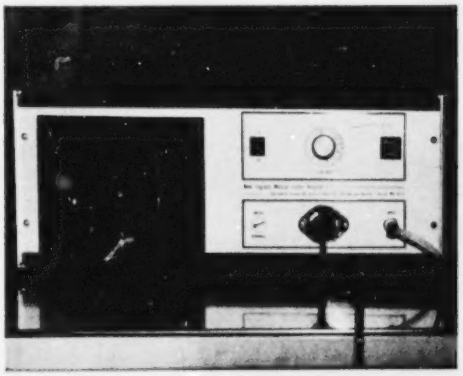
the rank order of characters in the English language. This represents an approximate 30% speed improvement over an alphabetically-ordered visual keyboard.

Recent developments in low power electronics have offerred the potential for battery operation of the TIC. Since funding for redesign of tnis device was not readily available, the program staff proceeded cautiously, looking for an appropriate time for a design change.



Rear Panel of the TIC
Fig. 2

The current equipment modifications are actually taking place in two directions. The present TIC offers a 32-character electronic display, and a paper strip printer. These functions are being transferred into a smaller, portable unit with an operating life of eight hours before recharging is necessary. The existing TIC, for which a large price has been payed for tooling development, will simultaneously be upgraded into a more powerful communication tool. This device will offer a complete video display that can be edited and modified by the user. The corrected text can then be "dumped" onto a typed page. This will hopefully provide the flexibility required for academic and vocational activities.

The Dictionary

Each person who communicates either through written or spoken language tends to use a vocabulary that is smaller than that actually at his disposal[2]. This may be evident in conversational idioms, or in key words or phrases (i.e. jargon) of a geographical location, or business environment. Part of the Non-Vocal Communication Program's activities has been to identify ways of shortening the user's time involved in transmitting a message. The method chosen has been to incorporate a dictionary of 400 words or phrases that can be custom programmed into a personalized TIC. The new circuit card can accommodate 4 increments of 1000 letters. Therefore the complete dictionary will consist of no more than 400 entries whose total length is no longer than 4000 letters. While this provides an average of 10 characters per entry, the actual word or phrase lengths will be independently set.

The selection of such a large number of entries offerred a challenge in the design of a visual keyboard. The magnitude of a 456 entry keyboard (400 words + the standard TIC keyboard) would prevent efficient use due to long scanning times. An encoded method was determined to be the desirable approach. The bottom row of the TIC keyboard is designated with the numbers one through eight, indicating dictionary page numbers. Each character of the existing keyboard will represent a different word on each page. Selection of a word is accomplished by first choosing a page number, and then the appropriate keyboard character. The desired word will be taken from the dictionary memory and displayed on the output device.

Anticipatory Communication[3]

An important consideration in the application of a communication device is the speed with which its operator can make an output. The rate of output is limited by both the user's input time response, and the size of the scanned visual keyboard. Although the vocabulary and verbal skills of the user are expected to improve with training, the physical input cannot be expected to do the same. Disabilities such as cerebral palsy do not generally change dramatically and will most likely require the user to use the same grossly controlled input motion for his lifetime. ALS is a progressive disease and will result in a loss of motor control over time.

As can be understood from above, the easy solution of "speeding up" the scan rate is impractical. Improvement cannot be found in reducing the keyboard size since the TIC keyboard contains essential entries for alphabetic and numeric output as well as punctuation and arithmetic symbols.

A major effort of the BMEC has been to study the application of language redundancy to this rate problem. Results of the project have shown a theoretical improvement of approximately 50% over the standard TIC. Present studies are focusing on the display techniques that will maintain this level of improvement when the device is used by a human operator.

Based upon knowing no prior characters p=.19
Based upon knowing 1 prior character p=.28
Based upon knowing 2 prior characters p=.40
Based upon knowing 3 prior characters p=.51

Probability of Correctly Predicting
the next Character to be Typed
Fig. 3

The current state of the research has yielded a prototype device appropriately named the ANTIC (Anticipatory TIC) which predicts the six most likely letters to follow the letter most recently chosen. This prototype is being studied with the assistance of a high-level spinal cord injured client who is providing valuable information on its acceptability as a working design. In order to reach the 50% improvement, the statistics on letter frequency will be based not upon the single prior choice, but upon the three previous selections.

Symbol Communication

All of the above devices require that the user have the ability to spell, or at least

recognize words from the dictionary. Within the Non-Vocal Communication Project there has been identified the need for a less sophisticated device that will identify locations rather than character symbols. The solution to this need has been a small relatively inexpensive device that offers the user the choice of eight or 48 squares. Filling these squares will be symbols, letters, or pictures attached to small plastic clips. The same type of switch as is used in the TIC or ANTIC can stop the scanning at a particular symbol and cause the light to flash as an indication of choice. The Symbol TIC or SYMTIC scans the eight squares in a linear fashion, or scans the 48 in a row-column manner. There is no printout provided in the unit. The SYMTIC is envisioned as a teaching tool for early intervention with non-readers and can be used with various teaching systems such as the Peabody Rebus Reading Program[4], or the alternative language programs like the Bliss Symbolics.[5]

Symbol Printing

The principal difficulty encountered with the SYMTIC is its lack of a printed output. This prevents the user from communicating independently since his listener must remain within viewing distance.

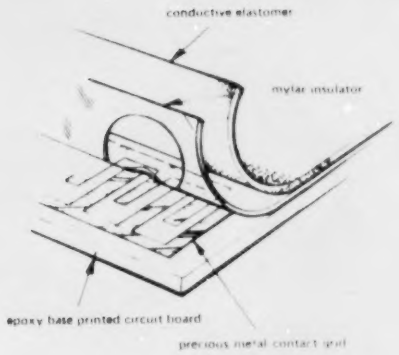
The BMEC is trying to rectify this situation by developing a printing unit that will reproduce graphic symbols. The Cryptographic TIC or CRYPTIC will initially be programmed for use with the Bliss Symbols and will be assigned to the Vermont Achievement Center in Rutland, Vermont.

Electronic Letterboard

The devices described throughout this paper have been operated by a single input switch. Many non-vocal individuals are capable of greater interaction with a machine. Letterboards have been commonly used by those clients who have some residual pointing ability or the use of a head-pointer. Letterboards[6] have the advantage of being inexpensive and entirely flexible since they are only paper on which a teacher or clinician writes words and letters, or draws pictures. The locations of these objects can be determined according to the physical abilities of the user. Midline crossing problems, hand preference, or varying dexterity can be minimized by the proper placement of the symbols.

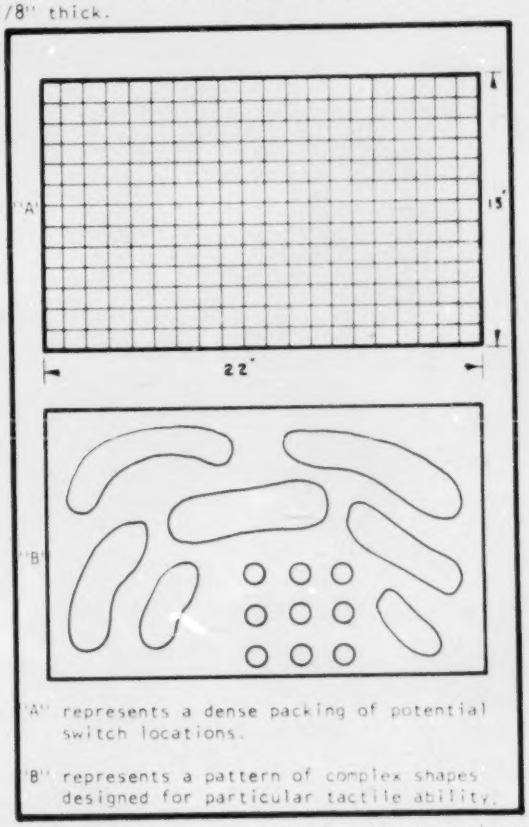
Electronic conversion of these letterboards has not been able to offer the same flexibility. The use of mechanical switches and sensors presents physical limitations that prohibit total flexibility. Expanded typewriter keyboards offer a fixed arrangement that may often be unsatisfactory to a user. Varying the size of that keyboard or even changing the size of the switches becomes a major mechanical task. The Autocon[7] from the University of Wisconsin offers an attempt at flexibility with several optional arrangements of the magnetic proximity switches.

The BMEC has contracted with the Flex Key Corporation of Gloucester, Massachusetts for the fabrication of a flat switch panel that measures 22" x 15" and contains 4000 switch contacts arranged in a honeycombed grid. The Flex Key Corp. has graciously donated the engineering time required in the design of the switch panel.



Elastomeric Switch Structure
Fig. 4

The switching mechanism is a proprietary process owned by Flex Key[8] and utilizes the properties of a conductive elastomer. The entire panel consists of a large printed circuit card and a layer of elastomer separated by a mylar insulator. The entire panel is approximately 1/8" thick.



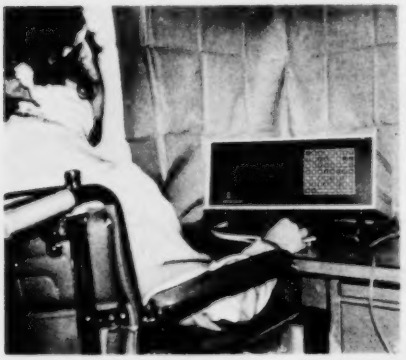
"A" represents a dense packing of potential switch locations.

"B" represents a pattern of complex shapes designed for particular tactile ability.

Samples of Complex and Custom Tactile Communicator Layout
Fig. 5

The switch contacts are .25" in diameter on .30 inch centers. Assuming that the smallest object pointing to the panel will be a human finger, at least one of the switches will be closed when the panel is touched. Once the switch closure is made, the X and Y coordinates of the contact will be detected by external circuitry. The force required to register an input is less than 10 ounces. The switch movement is .005 inches.

That external circuitry is now being developed and will allow the teacher or clinician to define clusters of switches as words or letters. In this way a totally flexible letterboard surface may be custom designed to meet the user's needs. The logic circuitry will identify the appropriate input and operate the same type of printing devices as are already in use in the TIC.



Tufts Interactive Communicator in Clinical Setting
Fig. 6

Technology Utilization Project

The Biomedical Engineering Center has felt an obligation to make available the results of its research and development. This has already been evident in the project within the State of Massachusetts. Other devices have also been made available to individuals and institutions for use in their own programs. The BMEC tries to maintain contact with these sites and provide any possible assistance. All devices have been offerred as a service of Tufts-New England Medical Center and are made available on a non-profit basis.

Acknowledgement

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